The National Institute of Mental Health, NIH

Division of Basic and Clinical Neuroscience Research

The Fifth Annual DYNAMICAL NEUROSCIENCE Satellite Symposium

"Integrating Observations Across Scales"

Marione, that is the soul of the autumn trees Egresi Zsuzsanna

Friday and Saturday -- October 24-25, 1997

Twenty-Seventh Annual Meeting of the Society for Neuroscience
Ernest N. Morial Convention Center
New Orleans, Louisiana

Rooms 2-4-6

The National Institute of Mental Health, NIH

Division of Basic and Clinical Neuroscience Research

The Fifth Annual
DYNAMICAL NEUROSCIENCE
Satellite Symposium

"Integrating Observations Across Scales"

This symposium will bring together leading theoretical and experimental neuroscientists to discuss how currently available technologies and data analytic methods are used to collect, store, analyze and visualize information. The emphasis will be on how to identify the most useful information in complex data sets. Several of the obstacles faced by experimentalists in handling very large and incomplete data sets will be addressed, including discussions regarding data compression and display. The objective is not to provide a detailed account of individual methods and techniques, but rather to examine how investigators go about identifying important or relevant information at different scales. For example, techniques that are helpful in representing spatiotemporal processes at one scale (e.g., multiple units) may be useful at other scales (e.g., fMRI). By bringing together experts who use different approaches and technologies across a range of experimental model systems, the hope is to enhance understanding on how different scales of observation and organization are linked. Invited Speakers are: Scott Kelso, Karl Friston, Giulio Tononi, Jeffrey Sutton, Ehud Kaplan, Martin Sereno, Miguel Nicolelis, Naftali Tishby, Ellen Covey, Jay McClelland and Keynote Speaker Deborah Gordon.

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http://www.nimh.nih.gov/dbcnr.dyn97.htm

DYNAMICAL NEUROSCIENCE

"Integrating Observations Across Scales"

Rooms 2-4-6 of the Convention Center

Friday, October 24

8:30 Registration and Continental Breakfast

9:00 **Dennis L. Glanzman** and
Stephen H. Koslow
National Institute of Mental Health
Introduction and Welcome

9:15 **Jeffrey Sutton**
Harvard Medical School
Investigating Network Dynamics at Different Scales: Theory and Experimentation

10:15 **Ehud Kaplan**
Mount Sinai School of Medicine
Color, Size and All the Rest: How Do They All Fit in the Visual Cortex?

11:15 *Coffee Break*

11:45 **Martin Sereno**
University of California at San Diego
Brain Imaging and Circuit Models: Getting into the Same Ballpark

12:45 *Lunch*

2:00 **J.A. Scott Kelso**
Florida Atlantic University
Linking Levels of Brain and Behavioral Self-Organization: Concepts, Experiments, Theory

3:00 **Karl Friston**
University College, London
Neural Codes, Transients and Metastability

4:00 *Coffee Break*

4:30 **Andrew Schwartz**
The Neuroscience Institute
San Diego, California
Representation of Arm Kinematics in Motor Cortex and their Transformation to Muscle Activation

5:30 **Jay McClelland**
Carnegie Mellon University
Discussion: *Approaches to Dynamical Neuroscience*

6:00 Main Meeting Adjourns
Symposium Banquet Begins
Rooms 10-12-14 of the Convention Center

8:00 ***Keynote Address*:**
Deborah Gordon
Stanford University
How Ants Decide and Colonies Act
Rooms 2-4-6 of the Convention Center

DYNAMICAL NEUROSCIENCE
"Integrating Observations Across Scales"

Rooms 2-4-6 of the Convention Center

Saturday, October 25

8:30 Registration and Continental Breakfast

9:00 Morning Announcements

9:15 **Miguel Nicolelis**
Duke University
Distributed Processing of Sensory Information in the Mammalian Brain

10:15 **Naftali Tishby**
Hebrew University, Jerusalem
Using Hidden Markov Models to Characterize Internal Brain States

11:15 *Coffee Break*

11:45 **Ellen Covey**
University of Washington
Representation of Auditory Temporal Patterns on Multiple Scales: Relating Intracellular, Single-Unit and Population Data

12:45 **Jay McClelland**
Carnegie Mellon University
Overview and Summary

1:30 Main Meeting Ends

2:00 **Poster Session**
Hall "A" of the Convention Center
(Lunch will be available for purchase at the poster session)

Investigating Network Dynamics at Different Scales: Theory and Experimentation

Jeffrey Sutton, Harvard Medical School

In 1995, Sutton and Anderson proposed a model of dynamic clustering among small neocortical networks. Termed the Network of Networks, the model has been applied to several problems in computational neuroscience and engineering, as well to the registration of human fMRI data across different scales and across different tasks (e.g., motor tasks, normal and altered language processing). Because vascular responses couple fMRI signals for several seconds, some investigations of dynamical responses have been conducted using simultaneous elecrophysiological recordings. Studies across physiological state (e.g., wake-sleep) have been performed and provide new insights into how large regions of the brain interact in time. The complementary theoretical and experimental approaches attempt to link network events and mechanisms at multiple spatial and temporal scales.

Color, Size and All the Rest: How do They All Fit in the Visual Cortex?

Ehud Kaplan, Jules & Doris Stein Research-to-Prevent-Blindness Professor, Departments of Ophthalmology, Physiology & Biophysics, Box 1183, The Mount Sinai School of Medicine, One Gustave Levy Place, New York, NY, 10029

The primary visual cortex is widely believed to be organized in a modular fashion. Optical imaging of intrinsic neuronal signals in the brain provides a new tool with which to explore the functional architecture of the brain. We have used extensions of principal component analysis to explore the relationships among the various functional maps which can be imaged in the visual cortex of cats and monkeys, maps which represent neuronal clusters related to orientation, ocularity, size or color of the stimulus. Our research allows us to assess, for each map, the spatial scale of the structures of each functional map, and this makes possible a direct evaluation of the cortical modularity hypothesis.

Brain Imaging and Circuit Models: Getting into the Same Ballpark

Martin I. Sereno, Ph.D., Department of Cognitive Science, University of California, San Diego, La Jolla, CA 92091-0515

The recent explosive growth of human brain imaging has been fueled particularly by technical advances in fMRI and analysis methods. Advances in mapping sensory areas on the unfolded cortical surface are described. There remains, however, a troubling gap between the spatial and temporal resolution of current non-invasive imaging techniques and the resolution necessary to begin to make contact with circuit models, which have been developed largely on the basis of invasive experiments in animals. In the second part of the talk, single-unit evidence for the widespread existence of a new kind of continuous attractor network is presented. Finally, current prospects for non-invasively imaging circuit level phenomena are realistically assessed.

Linking Levels of Brain and Behavioral Self-Organization: Concepts, Experiments, Theory

J. A. Scott Kelso, V. K. Jirsa & A. Fuchs, Program in Complex Systems and Brain Sciences, Florida Atlantic University, Boca Raton, Florida

The anatomical heterogeneity and functional complexity of the human brain render it unlikely that purely top-down or bottom-up approaches will succeed, or that there will ever be (as in some cases in physics) a single step, micro-macro reduction. In this talk I will illustrate a strategy more akin to a level-by-level stitching process. This strategy proceeds in the following steps: 1) Use general concepts of pattern formation in open, nonequilibrium systems (collective variables, instability, etc.) to motivate experiments on "simple" sensorimotor coordination; 2) From these observations identify relevant collective variables and their dynamics (equations of motion describing stability and change); 3) Test predictions of the behavioral dynamics at the level of cortical function, here using full-head, multisensor SQuID arrays combined with analysis techniques designed to capture the brain's behavior in both space and time; 4) Model the resulting spatiotemporal behavior of the brain using coupled, nonlinear dynamics; 5) Derive the latter from a deeper theory based on known neuroanatomical and neurophysiological properties of cortical cell assemblies and their connectivity; and 6) Use this theory to explain new experimental findings regarding how the cortex adaptively times behavior to meet changing environmental demands. This talk will focus primarily on Steps 5 and 6.

Neural Codes, Transients and Metastability

Karl Friston, Wellcome Department of Cognitive Neurology, Institute of Neurology, University College, 12 Queen Square, London

The brain is a complicated system showing both functional segregation and integration. The special complexity of neuronal dynamics might, itself, indicate something about the nature of neuronal interactions and the integration among brain areas. The work discussed looks at the complexity of neuronal dynamics in terms of metastability; the intermittent and recurrent expression of transients that have a distinct frequency structure. One simple characterization, of this metastability, obtains from the changing spectral density of neuronal time-series. We will focus on the genesis of neuronal transients by testing the hypothesis that distant cortical areas exert a modulatory influence, not on the dynamics intrinsic to the region in question, but on the underlying control parameters. The idea is that slow variations of activity in remote cortical areas modulate or facilitate the expression of specific, high frequency, transients. We tested this hypothesis using neuromagnetic (MEG) signals from parietal and prefrontal cortex. We found that nonlinear functions of parietal activity (with time-constants in the order of 100 ms) could predict a significant portion of the dynamic changes in gamma activity in the prefrontal region. This sort of modulatory, nonlinear coupling results in metastable dynamics that could reflect transactions between different brain areas that employ neuronal transients.

Representation of Arm Kinematics in Motor Cortex and Their Transformation to Muscle Activation

Andrew B. Schwartz, The Neurosciences Institute, 10640 John Jay Hopkins Drive, San Diego, CA 92121

By considering time and speed, we have been able to extend the characterization of movement direction as the primary determinant of motor cortical activity during arm movement. Drawing is a task where the arm varies its speed and direction within a continuous movement. We have recorded the activity of cortical cells as monkeys performed a variety of drawing tasks and have shown how speed and direction are represented together in the cortical population, how this interaction might be responsible for the observed psychophysical invariants of drawing and that in general, the trajectory of the hand is well represented by the motor cortical population. The correlation between motor cortical neuronal and muscle activity changes during the drawing task. We have calculated the joint angles and carefully measured the origin and insertion of the monkey's arm muscles. This made it possible to calculate the muscle-induced hand acceleration (MIHA), an instantaneous measure of the hand's acceleration that would result from an impulse contraction of the muscle. The MIHA varies with the posture of the arm throughout the task. When the direction of the MIHA matches the preferred direction of a motor cortical neuron, that neuron's activity tends to be correlated with the muscle's activity. This can provide a straightforward description of the transformation of the cortical displacement signal to a set of muscle activations.

Discussion: Approaches to Dynamical Neuroscience

Jay McClelland, Carnegie Mellon University

There are several kinds of research that can be encompassed under the rubric of *"Dynamical Neuroscience"*. Some researchers search for quantities that can be called dynamical features of neural systems, while others seek more explicitly to understand the dynamics of neural information processing, i.e., the real-time neural processes that lead to functional outcomes for the behavior and cognition of the organism. The discussion will raise this distinction, consider the relationship between these two research approaches, and suggest that it would be fruitful if these two approaches could become more fully integrated.

KEYNOTE ADDRESS: How Ants Decide and Colonies Act

Deborah M. Gordon, Department of Biological Sciences, Stanford University, Stanford CA 94305-5020

An ant colony performs various tasks, such as foraging and nest construction. Numbers of workers engaged in each task change as external conditions and the needs of the colony vary. For example, when a new food source becomes available, more ants forage. Task allocation is the process that results in the numbers of ants in each task appropriate for the current situation. Task allocation operates without central control; no individual directs the work of others, and none is capable of global assessment of colony needs. Instead, task allocation at the colony level is the outcome of fairly simple decisions by individual ants. At the individual level, two kinds of events contribute to shifts in task allocation: individuals switch tasks, and individuals decide whether to perform a task actively or instead to be inactive. An ant's recent interactions with other ants influence its task decisions. Whether an ant is active, and which task it performs, depends on the rate or number of that ant's interactions with other task groups. Thus the cue is the interaction pattern, rather than the content of the message transmitted. Here interactions are brief antennal contacts; the antennae are the organs of chemical perception. Task groups differ in the chemical profile of hydrocarbons on the ant's cuticle, and such differences may permit an ant to distinguish the tasks of the other ants it meets. Interaction rates should depend on colony size, and the ants' use of interaction patterns may explain why task allocation changes as colonies grow older and larger.

Distributed Processing of Sensory Information in the Mammalian Brain

Miguel A. L. Nicolelis, Department of Neurobiology, Duke University Medical Center

The rat trigeminal somatosensory system was used a model to investigate how populations of neurons, located at multiple processing stages of the a sensory pathway, represent sensory information following passive and active tactile stimulation. Contrary to the traditional view of this sensory system, our results revealed the existence of highly dynamic and distributed representations of tactile information, not only in the somatosensory cortex, but also in the thalamus and even in the brainstem. In these structures, we identified broadly tuned neurons with multiwhisker receptive fields (RFs). In the thalamus, a large percentage of neurons exhibited shifts in the spatial domain of their RFs as a function of post-stimulus time. During these shifts, the center of the neuron’s RF moved across the whisker pad from caudal to rostral whiskers, but not in the opposite direction, suggesting that these spatiotemporal RFs may encode directional information. Simultaneous recordings of the activity of cortical and thalamic neurons carried out by Asif Ghazanfar, a graduate student in our laboratory, revealed that thalamocortical ensemble responses increase in a nonlinear fashion according to the extent and spatial orientation of the multiple-whisker stimuli. Supralinear responses were seen more frequently with vertically- than horizontally-oriented stimuli suggesting that thalamocortical interactions generate complex spatial transformations and that these are used by rats for tactile discrimination.

Using Hidden Markov Models to Characterize Internal Cortical States

Naftali Tishby Institute of Computer Science and Center for Neural Computation, The Hebrew University, Jerusalem 91904, Israel tishby@cs.huji.ac.il www.cs.huji.ac.il/~tishby {On sabbatical at: NEC Research Institute, 4 Independence Way, Princeton NJ; Email: tishby@research.nj.nec.com}

Multi-electrode recordings from the frontal cortex of behaving monkeys are analyzed as a multivariate process using hidden Markov models. Unlike other analysis methods the data is segmented into states of similar firing patterns without any alignments to external stimuli. We show that the states emerge from sharp transitions in the collective firing activity and clearly identify the behavioral modes of the animal. Moreover, the emergent states are characterized by different pairwise correlations, indicating truly different underlying cortical dynamics in different states of the model. Based on joint work with Itay Gat and Moshe Abeles.

Representation of Auditory Temporal Patterns on Multiple Scales: Relating Intracellular, Single-Unit and Population Data.

Ellen Covey, Department of Psychology, University of Washington, Seattle, WA 98195.

The central auditory system has evolved for the purpose of analyzing the complex pressure wave that results when waveforms from multiple sound sources mix and interfere with one another. The analyses performed by the central auditory system include picking out and grouping the waveforms that originate from a given source, localizing each sound source to a point in space, and extracting meaning from patterns of time-distributed information. In the brainstem, the auditory system diverges into multiple parallel pathways; these pathways converge once again at the level of the midbrain. To understand the specific role played by each pathway and the interactions among the pathways, we have used several different experimental approaches. These include extracellular recording of single neurons' responses to sound, intracellular recording in vivo using whole-cell patch clamp techniques, and analysis of population data obtained either through collating responses of multiple single units or through recording of evoked potentials. Comparison of the data obtained using such a variety of methods is especially instructive when comparing integration of information over different time scales. For example, measuring the respective time-courses of excitatory and inhibitory synaptic currents in midbrain auditory neurons has been a key factor in understanding the integrative processes that underlie the selectivity of these neurons for specific temporal patterns of sound, as seen through extracellular recordings. On a longer time scale, we are beginning to understand how a single short sound can set up a subthreshold pattern of changes in excitability that can influence the response to subsequent sounds for many seconds.

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ABSTRACTS OF POSTERS

1 ***Complex Approach to Study of the EEG Complexity*** . Vladimir E. Bondarenko, Institute of Biochemical Physics, Russian Academy of Sciences, Kosygin Street, 4, Moscow 117334, Russia.

2 ***Relations Among EEGs From Olfactory Bulb, Somatomotor, Auditory, Visual and Entorhinal Cortices of Trained Cats.*** G. Gaál and W.J. Freeman, University of California, Berkeley.

3 ***Nonlinear Dynamics of the Frequency Locking of Baroreceptor and Sympathetic Rhythms***. G.L. Gebber*, S. Zhong, S.-Y. Zhou, and S.M. Barman. Departments of Pharmacol./Toxicol. and Physiol., Michigan State University, East Lansing, MI.

4 ***Modeling Unipolar Depression Treatment Response and Recovery Dynamics: An Integrated and Convergent Approach*** . Joanne Luciano[1], Michael Cohen[2], Jacqueline Samson[3], and Michiro Negishi[2]. [1]Neural Systems Group, Massachusetts General Hospital, [2]Boston University, [3]Harvard Medical School.

5 ***An Oscillatory Network Model Accounts for the Sternberg and Sat Data on Short-term Memory and Predicts That Theta Frequency Should Vary with Memory Load*** . O. Jensen and J.E. Lisman*. Center for Complex Systems, Brandeis University, Waltham MA.

6 ***Analysis of Local Phase Gradients in Neocortical EEGs Gives Size Estimates of Coherent Activity Domains: A Novel Solution to the 'Binding Problem.'*** Walter J Freeman* and John M Barrie. Department of Molecular & Cell Biology, University of California, Berkeley.

7 ***Statistical Determination of Spiking Characteristics of Noisy Neurons*** . P.H.E. Tiesinga and Jorge V. José, Center for Interdisciplinary Research on Complex Systems, and Department of Physics, Northeastern University.

8 ***Spatio-Temporal Classification of fMRI Activation Centers*** . Kruggel F, von Cramon DYC, Max-Planck-Institute of Cognitive Neuroscience, Inselstrasse 22-26, 04103 Leipzig, Germany.

9 ***Noradrenaline Increases Signal-to-noise Ratios in Rat Frontal Cortex*** . B.A.Field*, N.D.Comsia and R.T. Marrocco. Institute of Neuroscience, University of Oregon.

10 ***Data Analysis and Modeling of Persistent Activity of the Monkey Prefrontal Cortical Neurons During Short-Term Memory Tasks*** . Ying-Hui Liu and Xiao-Jing Wang, Center for Complex Systems and Department of Physics, Brandeis University

11 ***Effects of Synaptic Depression on Temporal Nonlinearities in Responses of Model Simple Cells***. F.S.Chance*, S.B.Nelson, & L.F.Abbott, Dept. of Biology & Volen Center for Complex Systems, Brandeis University.

12 ***Facilitation of Feedback Inhibition May Underly Temporal Decorrelation in the LGN*** . Jeremy B. Caplan*, Xiao-Jing Wang, Center for Complex Systems and Department of Physics, Brandeis University.

13 ***Neural Networks for Chemotaxis in*** **C. elegans*****: Rule Extraction and Robotics*** . Thomas C. Ferree, Thomas M. Morse, and Shawn R. Lockery. Institute of Neuroscience, University of Oregon, Eugene, OR.

14 ***Noise Induced Spiral Waves in Astrocyte Syncytia Show Evidence of Self-organized Criticality***. Ann Cornell-Bell, Viatech Imaging, Ivoryton, CT, P. Jung, Dept. of Physics, Ohio University, Kathleen Shaver Madden, Foundation for Intern. Nonlinear Dynamics, Bethesda, MD, and F. Moss, Center for Neurodynamics, University of Missouri at St. Louis, St. Louis, MO.

15 ***Unstable Periodic Orbits in the Dynamical Activity of Thermally Sensitive Neurons*** . X. Pei and F. Moss, Center for Neurodynamics, University of Missouri at St. Louis, St. Louis, MO 63121 USA; H.A. Braun, M. Dewald, M. Huber, K. Voigt, Institute of Physiology, University of Marburg, Marburg, Germany.

16 ***The Pre-state and Spike Timing Precision of Oscillatory Neurons in the Paddlefish,*** **Polyodon spathula**. Xing Pei. Center for Neurodynamics, University of Missouri-St. Louis.

17 ***Electrical Sense in the Paddlefish,*** **Polyodon spathula**. X Pei, LA Wilkens, D Russell and F Moss. Center for Neurodynamics, University of Missouri-St. Louis.

18 ***Human Interpretation of Noisy Visual Detail Revealed by Psychophysics and fMRI*** . E. Simonotto (1, 2) M. Riani (2) F. Spano (2) F. Levrero (3) A. Pillot (3), R.C. Parodi (4) F. Sardanelli (5) P. Vitali (6) J. Twitty (1) F. Moss (1); (1) Center for Neurodynamics, University of Missouri at St. Louis, St. Louis, MO USA; (2) INFM - Unit of Genova; (3) Medical Physics Department, S. Martino Hospital; (4) Neuroradiology Department, S. Martino Hospital; (5) Radiology Department, Univ. of Genova; (6) Neurophysiology Department, S. Martino Hospital, Genova, Italy.

19 ***Discharge Patterns of Thalamic Visual Neurons in the Awake Cat During Alert and Drowsy States***. S. Lehmkuhle and N. Tumosa, Center for Neurodynamics, University of Missouri - St. Louis, St., Louis, MO 63121 USA.

20 ***Population State Diagrams Applied to Large Scale Models*** . J.P.A.Foweraker, D.P.Bashor1 & M.Hulliger. Dept. of Clinical Neurosciences, University of Calgary, and, (1) Dept. of Biology, University of North Carolina.

21 ***Statistical Approaches to Place Field Estimation and Neuronal Ensemble Decoding*** . 1E.N. Brown,* 2L. Frank, 1D. Tang, 2M. Quirk and 2M. Wilson. 1Dept. of Anes. & Critical Care, Massachusetts General Hospital, Boston, and 2Department of Brain and Cognitive Science, Massachusetts Institute of Technology.

22 ***Defining Causal Interactions Between Distributed Neural Ensembles Through Directed Coherence.*** K. Sameshima1, L.A. Baccala2, E. Fanselow3, and M.A.L. Nicolelis3. School of Medicine1 and Escola Politécnica2, Univ. Sao Paulo, SP, Brazil, Dept. Neurobiology3, Duke Universitiy.

23 ***Extracellular Recording from Adjacent Neurons: a Maximum-likelihood Solution to the Spike Separation Problem*** . M. Sahani (1,2), J. S. Pezaris (2) & R. A. Andersen (1,2). (1) Sloan Center for Theoretical Neuroscience and (2) Computation and Neural Systems, 216-76 California Institute of Technology.

24 ***Computational Consequences of Temporal Order in Synaptic Plasticity*** . P. D. Roberts and C. C. Bell. R.S. Dow Neurological Sciences Institute, Portland, OR.

25 ***Levels of Visual Processing in a Non-retinotopic Human Cortical Area*** . C.W. Tyler(1), H.A. Baseler(2) and B.A. Wandell(2)*. (1) The Smith-Kettlewell Eye Research Institute, San Francisco, CA, and (2) Dept. of Psychology, Stanford University.

26 ***Bootstrap Statistics Provide Error Estimates for Dimension Computations*** . M. Shelhamer. Johns Hopkins University School of Medicine.

27 ***An Oscillating Cortical Network Model of Sensory-Motor Timing and Coordination*** . Bill Baird. Department of Mathematics, University of California, Berkeley

28 ***Investigating Human Coordination with Peripheral Nerve and Transcranial Magnetic Stimulation***. R.G. Carson1, S. Riek1, and P. Bawa2. 1Department of Human Movement Studies, The University of Queensland, Brisbane, Qld, 4072, Australia. 2School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada, V5A 1S6.

29 ***Software Instruments for Quantifying Digital Video Spike Trains***. D. Debowy, S. Lu, J.Y. Ro and E.P. Gardner. Department of Physiology and Neuroscience, NYU Medical Center, New York.

30 ***A Study of Oscillations vs. Spiking in the Thalamic Network Model***. Karen Moxon, Rowshanak Hashemiyoon, and John K. Chapin, Department of Neurobiology and Anatomy, Allegheny University of the Health Sciences; Philadelphia, PA.

31 ***Linking Levels of Brain and Behavior: A Field Theoretical Approach***. V.K. Jirsa, A. Fuchs, J.A.S. Kelso. Program in Complex Systems and Brain Sciences Center for Complex Systems Florida Atlantic University, Boca Raton, FL.

32 ***Correlation Between Brain Activity and Motor Behavior: Theory and Experiment***. A. Fuchs, V.K. Jirsa, J.A.S. Kelso, Program in Complex Systems and Brain Sciences, Center for Complex Systems, Florida Atlantic University, Boca Raton, FL.

NATIONAL INSTITUTE OF MENTAL HEALTH (NIMH)
Parklawn Building
5600 Fishers Lane
Rockville, MD 20857
Area Code (301)

DIVISION OF BASIC AND CLINICAL NEUROSCIENCE RESEARCH
Fax: 443-1731

Stephen H. Koslow, Ph.D.	Division Director	11-103	443-3563	koz@helix.nih.gov
Walter L. Goldschmidts, Ph.D.	Associate Director for Research Training and Research Development	11-103	443-3563	wg8u@nih.gov
Debra K. Wynne, M.S.W.	Coordinator, Training and Education Pgms	11-103	443-3563	dwynne1@nih.gov
Michael F. Huerta, Ph.D.	Associate Director for Translational Research and Scientific Technology	11-103	443-3563	mhuerta@helix.nih.gov
{vacant}	Deputy Associate Director for Translational Research and Scientific Technology	11-103	443-3563	
Muriel Asher	Translational Research & Scientific Technol	11-103	443-3563	masher@helix.nih.gov
Mary F. Curvey	Fellowships and MERIT Program	11-103	443-3563	mary_curvey@nih.gov

Research Branches
Fax: 443-4822

Behavioral and Integrative Neuroscience Research Branch

Stephen L. Foote, Ph.D.	Branch Chief	11C-16	443-1576	sfoote@helix.nih.gov
Dennis L. Glanzman, Ph.D.	Chief, Theoretical and Computational Neuroscience Research Program	11C-16	443-1576	glanzman@helix.nih.gov
Israel I. Lederhendler, Ph.D.	Chief, Basic Behavioral & Systems Neuroscience Program	11C-16	443-1576	ilu@helix.nih.gov
Kevin J. Quinn, Ph.D.	Chief, Cognitive Neuroscience Program	11C-16	443-1576	kevin_quinn@nih.gov
Jack D. Maser, Ph.D.	Chief, Integrative Neuroscience of Schizophrenia, Mood and Other Brain Disorders Program	11C-16	443-9124	jmaser@nih.gov

Molecular and Cellular Neuroscience Research Branch

Steven J. Zalcman, M.D.	Branch Chief	11C-06	443-5288	szalcman@helix.nih.gov
Chiiko Asanuma, Ph.D.	Chief, Signal Transduction Program	11C-06	443-5288	cs2j@nih.gov
John Hsiao, M.D.	Chief, Molecular and Cellular Basis of Schiz. Mood and Other Brain Disorders Program	11C-06	443-5288	jhsiao@helix.nih.gov
Douglas L. Meinecke, Ph.D.	Chief, Developmental Neuroscience Pgm	11C-06	443-5288	dmein@helix.nih.gov
Ljubisa Vitkovic, Ph.D.	Chief, Neuroendocrinology / Neuroimmunology Program	11C-06	443-5288	vitkovic@helix.nih.gov

Preclinical and Clinical Therapeutics Branch

Linda S. Brady, Ph.D.	Acting Branch Chief, and Chief, Neuropharmacology and Drug Discovery Program	10C-24	443-9875	lb@helix.nih.gov
{vacant}	Clinical Pharmacology Program (Phase I & II)	10C-24	443-9875	
{vacant}	Psychopharmacology Program	10C-24	443-9875	

Genetics Research Branch

Steven O. Moldin, Ph.D.	Acting Branch Chief, and Chief, Genetic Basis of Schizophrenia, Mood and Other Brain Disorders Program	10C-26	443-9869	steve@hohut.nimh.nih.gov
Mary E. Farmer, M.D.	Chief, Genetic Basis of Behavior Program	10C-26	443-9869	mary_farmer@nih.gov
{vacant}	Genetic Basis of Neural Function Program	10C-26	443-9869	